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FINITE ELEMENT ANALYSIS OF HYBRID AND NON-HBYRID LAMINATE COMPOSITE

KM Galib*, Shah Rahman**
*(*Mechanical Engineering, Bangladesh University of Engineering and Technology, Detroit, MI, USA*
Email: Lgalib6@gmail.com)
** (*Shah Rahman, Bangladesh University of Engineering and Technology, NYCT, NY, USA*
Email: srahman2603@gmail.com)

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Abstract:

At present time composite materials are being used extensively in the engineered materials market ranging from everyday products to sophisticated machine applications. Composites can meet diverse design requirements with significant weight savings as well as high strength-to-weight ratio compared to conventional materials. But it is important to examine, understand and disseminate the reaction of composite material to relevant and appropriate conditions to ensure safe and effective utilization of composite materials. Finite Element Analysis of composite material is done to examine the behavior against various boundary condition and loading. This paper presents the Finite Element Analysis of a hybrid laminated structure using FEA software namely ANSYS and present the graphical results to compare the stress distribution obtained with that of non-hybrid composite structure. Structure used was a column of I shape composed of boron and glass fiber in epoxy matrix in different fiber orientation angle. I-shape of column was chosen particularly because of presence of sharp edge which is a topic of interest in case of FEA of composite materials. Stress distribution of two different layers at critical sections of the column was examined and the results are presented.

Keywords **— Hybrid composite material, Finite element analysis, ANSYS.**

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I. INTRODUCTION

Composites are becoming a very important key material in engineering world because of their advantages such as low weight, corrosion resistance, high fatigue strength, faster assembly, etc. Composites are used in products like aircraft components, golf clubs, electronic packaging, medical equipment, and space vehicles, even in home building [1]. By choosing an appropriate combination of matrix and reinforcement material, a new material can be made that exactly meets the requirements of a particular application. Composites also provide design flexibility because many of them can be molded into complex shapes [2]. A structural component such as beam or column made of composite material offers higher strength compared to conventional beam or column while weighing less. The finite element analysis is a numerical technique for finding approximate solutions to boundary value problems for partial differential equations. FEA subdivides a large problem into smaller, simpler, parts, called finite elements. The simple equations that model these finite elements are then assembled into a larger system of equations that models the entire problem [3]. Some popular FEA analysis software is ANSYS, ABAQUS, SAP2000, and COMSOL. The objective of our work was to perform Finite Element Analysis of a hybrid laminated structure using FEA software, compare the stress distribution obtained with that of a normal composite structure. Structures used was a column of I shape composed of boron and glass fiber in epoxy matrix. Corresponding graphs of normal, transverse and shear stress with respect to normalized distance of the layers are presented and discussed in this paper..

II. METHODOLOGY

When two or more fibers within a single matrix are incorporated, the resulting composite material is called hybrid composite material [4]. The hybrid composites offer advantages regarding structural integrity and sustained load under crash and impact conditions. On the other hand, Laminate is the type of composite that uses the filler material in form of sheet instead of round particles or fibers. Since the composites are non-homogeneous, the resulting properties will be the combination of the properties of the constituent materials [5]. The different type of loading may call on different component of the composite to take the load. This implies that the material properties of composite materials may be different in tension and in compression as well as in bending [6]. Laminates used in this analysis was made of fibers of boron and glass impregnated in epoxy resin as matrix. The hybrid composite is made by stacking 16 layers of glass-epoxy and boron-epoxy lamina in specified order. As it is known that the directionality of long fiber composite will depend on the direction in which the fibers are laid out in the composite. The lay-up could be done in a manner where the fibers all line up in one direction. This is called uniaxial composite [7]. And when the fibers are arranged alternately at an angle relative to a co-ordinate system, this is called generally orthotropic composite. A laminate is made of a group of single layers bonded to each other [8]. Each layer can be identified by its location in the laminate, its material, and its angle of orientation with a reference axis. Each lamina is represented by the angle of ply and separated from other plies by a slash sign. This is called the laminate code. The first ply is the top ply of the laminate. Laminate code for hybrid composite used in this analysis is:

$$[\pm75^B/\pm30^G/\pm30^G/\pm75^B]_S$$

Here the first layer composes of boron fibers placed at an angle of positive 75 degree with principal axis and the following layer is made of boron fibers placed at negative 75 degree. Whereas third, fourth, fifth and sixth layer is made of glass epoxy at positive and negative 30 degree lamina respectively. And seventh and eighth layer is just the same as first and second layer. Rests of the layers are placed symmetrically about the mid plane. For non-hybrid composite laminate code is:

$$[\pm75/\pm30/\pm30/\pm75]_S$$

This signifies that stacking sequence for non-hybrid is just the same as hybrid composite but all the laminas are composed of either glass epoxy or boron epoxy.

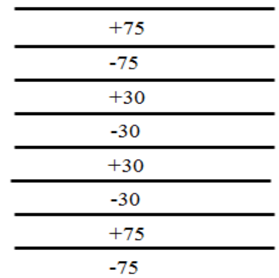

Fig. 1: Laminate code of hybrid composite material

Properties of glass epoxy and boron epoxy are:

Table 1: Properties of glass epoxy and boron epoxy

Properties	Glass epoxy	Boron epoxy
E_1 (Longitudinal Young's modulus)	2.04 GPa	38.6 GPa
E_2 (Transverse Young's modulus)	18.5 GPa	8.27 GPa
μ_{12} (Major Poisson ratio)	0.23	0.26
G_{12} (Shear modulus)	5.59 GPa	4.14 GPa

In case of column, horizontal direction lies along X axis and vertical direction along Y axis. Length along X axis is D while height along Y axis is L. Also top and bottom part of I is 20 percent of total length, that is 0.2L and the middle portion or stalk part is 60 percent of total length i.e. 0.6L. Adding all three sections gives us, 0.2L+0.6L+0.2L=L. Numerical dimensions are given by, L=40cm, D=10cm. In this analysis roller and fixed supports were used to restrict deformation in desired axes. For the column, fixed support was placed al L=0 and roller support at L=0.8L to L at both sides of the top section. Here roller support restricts horizontal movement along x axis. Boundary conditions are expressed by:

Roller: $u_y=0$
Fixed support: $u_x=u_y=u_z=0$

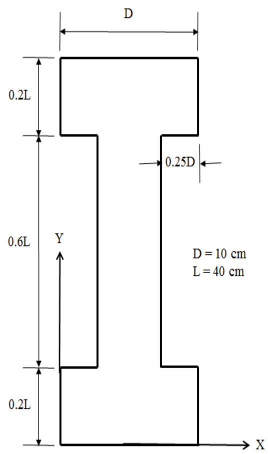

Fig. 2: Dimensions of the I column

Load was applied to see the deformation and stress distribution in critical sections of the structures. Load applied was uniform and 3 MPa in magnitude, and placed on the half of top line. In our analysis we used shell 181 element for ANSYS. SHELL181 is suitable for analyzing thin to moderately-thick shell structures. It is a four-node element with six degrees of freedom at each node: translations in the x, y, and z directions, and rotations about the x, y, and z-axes [9]. In this analysis total number of nodes along both horizontal and vertical line is 101. Meshing is the process of breaking up the model into smaller pieces that can be solved by the software using advanced matrix math and then merged together to the correct result for the whole [10]. Meshing is one of the most important tasks of the FEA process. It has significant impact on the whole process. So meshing has to be done carefully. The goal is to create a mesh that accurately represent the stresses and displacements that will be present in the real life application of a part without taking up too much computing power and time. The importance of generating high quality mesh can never be overemphasized. Sharaban et al showed the effect of element quality and number on accuracy of the FEA [11]. Mesh can be automatically generated in ANSYS but that will not produce sufficiently accurate result. To obtain a more accurate result, mesh refinement is necessary. In this work, meshing has been done manually. First all the lines comprising the boundary of the model was divided into equal number, then meshing was done to ensure uniform meshing all over the structure. In this work all horizontal and vertical lines were divided into 100 parts generating 100x100 elements.

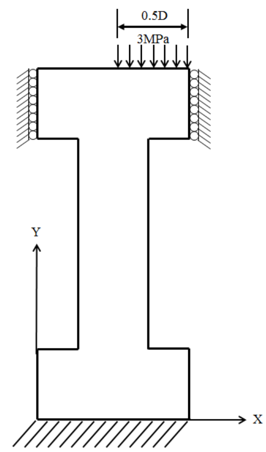

Fig. 3: Constrains and load applied on the column

III. RESULTS

Comparison between hybrid and non-hybrid laminated structures shows that, stress induction act differently for same composite in these structures. Boron epoxy is compared in these structures for the same layers generate different stress values. In hybrid structure boron epoxy has adjacent layer of glass epoxy, this might be the reason to higher stress generation [12]. Different angle ply play key role to this result. As second modulus of elasticity (Transverse Young's modulus) of glass epoxy has larger value than boron epoxy so between adjacent layers they share their generated stress. So proper angle ply selection of different layers in hybrid structure is very important [13]. Without proper selection of plies a very higher modulus of elasticity may act poorly.

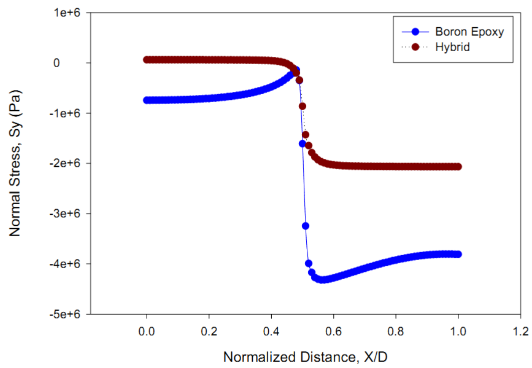

Fig. 4: Normal stress along Y axis on nodes of line Y/L=1 for boron epoxy and hybrid column for layer 1(+75 degree)

Figure 4 shows the graphical comparison of nodal stress generation along Y axis on line Y/L=1.0 between boron epoxy and hybrid structures at layer 1 (+75 degree) of column. The nodes where load applied of the column shows compressive stress generation and other half shows tensile stress generation, where no load is applied. For both, stress induced is greater in boron epoxy structure.

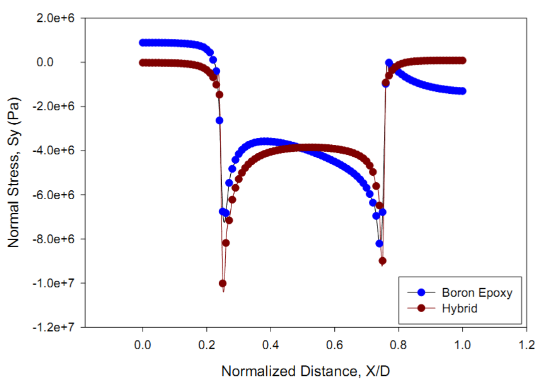

Fig. 5: Normal stress along Y axis on nodes of line Y/L=0.8 for boron epoxy and hybrid column for layer 1 (+75 degree)

For the same layer of column structure (+75 degree), normal stress induced on nodes of line Y/L=0.8 along Y axis of hybrid and boron epoxy structures is of particular interest due to presence of two singular points. All the nodes along the line have similar graphical shapes. But fluctuation of boron epoxy graph is greater at singular points than hybrid structure.

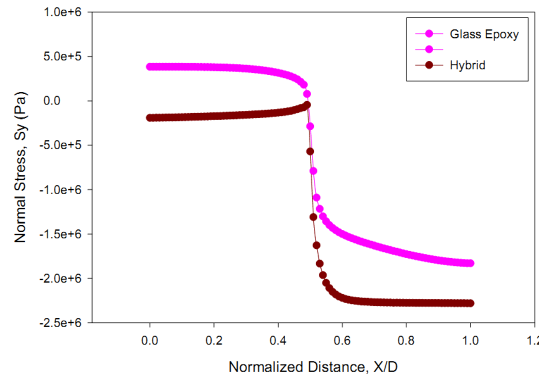

Fig. 6: Normal stress along Y axis on nodes of line Y/L=1 for glass epoxy and hybrid column for layer 3 (+30 degree)

For layer 3 (+30 degree) of both glass epoxy laminate and hybrid laminate, at line Y/L=1.0, compressive stress is generated on the nodes where 3.0 MPa load is applied. Here hybrid structure shows greater compressive stress generation on the nodes than the glass epoxy structure. Although, where no load is applied, tensile stress generation is observed due to boundary condition. On these nodes stress generation is greater on glass epoxy structure.

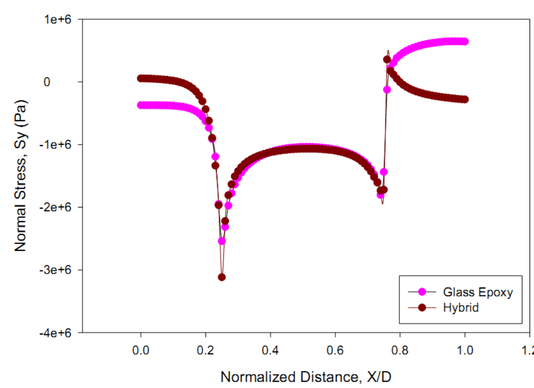

Fig. 7: Normal stress along on nodes along Y/L=0.8 for glass epoxy and hybrid column for layer 3 (+30 degree)

In the same layer there are two singular points on line Y/L=0.8. Both singular points show that greater stress generation is on hybrid structure than glass epoxy column. This observation may represent that stress induced is greater on hybrid structures than glass epoxy structure. Shear stress of column indicates not only stress but also failures of plies of relative positions. As structure is considered multi bodied as a whole, shear stress analysis might be also reveal useful information to analyze relative movement of layers in the structure.

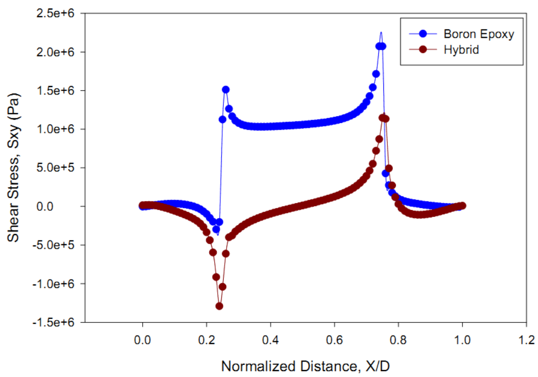

Fig. 8: Shear stress on nodes along Y/L=0.2 for boron epoxy and hybrid column for layer 1(+75 degree)

Shear stress generation is compared in layer 1 (+75 degree) on line Y/L=0.2 of boron epoxy and hybrid structures. Boron epoxy produces greater positive shear stress than hybrid structure. Also singular points can be seen fluctuating more in the boron epoxy structure.

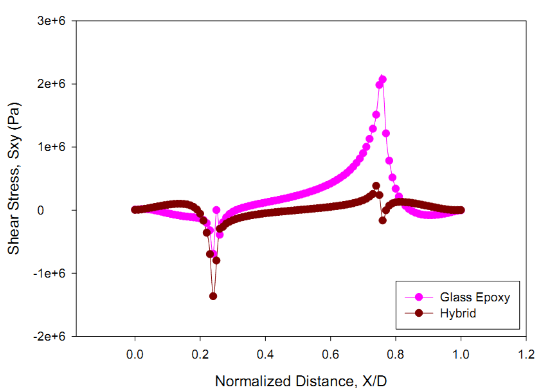

Fig. 9: Shear stress on nodes along line Y/L=0.2 for glass epoxy and hybrid column for layer 3 (+30 degree)

In case of comparison between glass epoxy and hybrid structure at layer 3(+30 degree), shear stress on nodes along line Y/L=0.2 indicates that both singular points have greater negative stress on hybrid structure than glass epoxy structure. Although some nodes at glass epoxy generate greater positive stress, this might be results of boundary conditions.

IV. CONCLUSIONS

This paper presents the Finite Element Analysis of a hybrid laminated structure using FEA software namely ANSYS and compare the stress distribution obtained with that of a normal composite structure. Structure used was a column of I shape composed of boron and glass fiber in epoxy matrix in different fiber orientation angle. In the column problem, 3 MPa pressure is applied to the upper half right end of the column structure. We have analyzed these problems with the help of FEM. This analysis tells us the result of using hybrid structure over composite structures. Individual analyzed layer of the hybrid and laminated structure have same physical properties. For the comparison between boron epoxy and hybrid structure, stress generation is greater in boron epoxy structure. And the stress generation is greater in hybrid structure, when it is compared with glass epoxy. For tensile stress, compressive stress and shear stress these results are valid.

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